WAVE ATTENUATION OF SALTMARSH VEGETATION UNDER STORM CONDITIONS

Ganga Caldera, Institut national de la recherche scientifique, Hollu.Caldera@inrs.ca
Jacob Stolle, Institut national de la recherche scientifique, Jacob.Stolle@inrs.ca
Damien Pham Van Bang, Institut national de la recherche scientifique, Damien.Pham_Van_Bang@inrs.ca
Andrew Cornett, University of Ottawa, acornet2@uottawa.ca
Enda Murphy, National Research Council of Canada,enda.murphy@nrc-cnrc.gc.ca
Ioan Nistor, University of Ottawa, inistor@uottawa.ca

BACKGROUND

Nature-based solutions (NbS) for coastal protection has recently gained increased attention worldwide as a sustainable, economical and eco-friendly alternative to conventional grey structures, particularly under the threat of climate change (Temmerman et al. 2013). The east coast of Canada is under pressure due to rising sea levels and isostatic adjustment (Savard et al. 2016) and the use of living shorelines has received broad attention to help protect local communities.

Wave energy dissipation by vegetation can be parameterized by the total horizontal force acting on the plant; expressed using a Morison-type equation considering only the form drag component (Dalrymple et al. 1984).

$$\epsilon_V = \overline{\int_{-h}^{-h+h_v} \frac{1}{2}\rho D N_S C_d\, u|u|\, u dz} \qquad [1]$$

where ϵ_V is the time-averaged wave dissipation constant per unit horizontal area, D is the stem diameter, h is the water depth, h_v is the plant height, N_s is the stem density, ρ is the density of fluid, C_d is the drag coefficient, and u is the flow velocity.

Modelling wave-vegetation interaction is challenging in a laboratory environment (Lara et al. 2016) and it is difficult to accomplish a realistic representation of a plant's biomechanical behavior and geometry using plant mimics or surrogates. Few studies have modelled real saltmarsh vegetation in large scale laboratory facilities (Möller et al. 2014; Maza et al. 2015) and quantified wave attenuation, particularly for engineered living shorelines (Maryland DoE, 2013). Further research is needed, particularly in the Canadian context, to investigate the capacity of different saltmarsh species to effectively attenuate waves and wave runup under storm conditions, to examine the plant's drag coefficient C_d and to bridge the gap to develop technical design specifications for the detailed design of living shorelines.

OBJECTIVES AND NOVELTY

With the long-term goal of supporting the development of the first technical design guidelines for NbS in Canada, this novel study aims to:

- Examine the species-specific wave attenuation and runup reduction.
- Investigate the overall attenuation capacity of a living shoreline.

This study is one of the first to examine the attenuation of waves by live plants in a sloped environment. The study will also provide critical validation data for numerical models to help with living shoreline design.

EXPERIMENTAL SETUP

The experiments were performed in the 5 m wide, 5 m deep and 120 m long large wave flume in the Laboratoire hydraulique environnemental (LHE) of Institut national de la recherche scientifique (INRS), Quebec City, Canada. A soil slope (1:20) of 80 m in length was installed in the flume with a 34 m long live saltmarsh with species native to the east coast of Canada. Three saltmarsh species were selected: *Spartina alterniflora* (pioneer marsh), *Spartina patens* (mid marsh) and *Spartina pectinata* (upper marsh).

A total number of 30 test conditions were selected with combinations of three different wave heights (0.15 m - 0.45 m), two different wave periods (4 s, 8 s) and three different water levels (2.4 m, 2.9 m, 3.4 m). The same test series was performed without vegetation (bare soil) as the reference test condition.

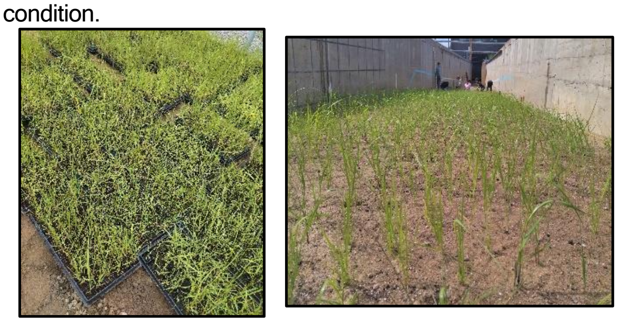

Figure 1 – Young saltmarsh plants before planting (left) and after planting in the wave flume (right).

Three vegetation patches were installed on the soil slope:18m long *Spartina alterniflora* vegetation as the pioneer marsh, 6m long *Spartina patens* as the mid marsh and 10m long *Spartina pectinata* as the upper marsh. All the saltmarsh plants were planted in the flume as juveniles and allowed to grow for three weeks after planting. During these three weeks, plants were watered daily and *Spartina alterniflora* plants were submerged for a minimum of four hours every second day.

Plant properties, such as height, stem diameter, and frontal area, were measured before the wave experiments started. Ten samples were also harvested to perform tensile tests and three-point bending tests measuring the plant's biomechanical properties.

The tests were started at the highest water level, with the smallest wave height and the period and progressively increased the wave conditions to avoid sudden failure of vegetation. Altogether twelve acoustic wave gauges were installed in the flume from the toe of the slope to the end of the last vegetation patch to measure the wave heights and periods. After each test condition water level was lowered and the slope profile was measured using a total station. All the selected test conditions were performed without vegetation (bare soil) as well to provide a reference case.

RESULTS AND DISCUSSION

Different saltmarsh species demonstrated different attenuation capacities. With these very young plants, significant plant uprooting was observed at the initial stage of the testing, especially with the young *Spartina patens* and *Spartina alterniflora* plants.

For *Spartina patens*, uprooting started at 0.15m wave height, 8s wave period and 2.9m water level which was close to the edge of the *Spartina patens* vegetation patch. Similarly, initial uprooting of *Spartina alterniflora* plants was observed at the 2.4m water level which was at the edge of this vegetation patch. The sediment scouring around the plants due to the wave breaking on these vegetation patches was observed as the main reason for the uprooting. On the other hand, this sudden uprooting was not identified for *Spartina pectinata* plants, instead, plants started to be damaged by stem breakage during the higher energy wave conditions.

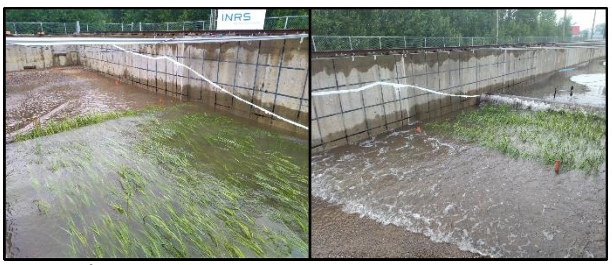

Figure 2 – Waves travelling over *Spartina pectinata* vegetation patch, H_s = 0.15 m, T_p = 4s, h = 3.4m.

Waves travelling on the slope were subjected to wave shoaling and eventually wave breaking and accordingly very dynamic change in the soil slope was observed including bar formation and migration on the slope.

However, in the current study due to shoaling and initial damage to the plants, minor wave attenuation was observed with vegetation compared previously observed flatbed cases. Furthermore, for the more energetic wave conditions, the majority of wave dissipation occurred due to wave breaking and the influence of the plants was negligible. The relative attenuation of each of the species was dependent on the wave height entering the marsh section. Overall, compared to the bare soil condition, the vegetated slope showed a minor wave energy attenuation and reduction of wave runup.

CONCLUSIONS

The following conclusions are drawn based on the objectives:

- Overall wave attenuation by the vegetated slope is minor compared to the vegetation on flatbed due to wave shoaling and other nonlinear effects
- Plants' maturity level, and above and below ground biomass amount are highly important factors that determine the endurance of plants under extreme wave conditions and efficacy in wave attenuation.

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